DRAFT PLAN FOR RESEARCH IN ENVIRONMENTALLY PREFERRED ADVANCED GENERATION TECHNOLOGIES

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I. BACKGROUND. Currently the vast majority of research in Environmentally Preferred Advanced Generation (EPAG) technologies is conducted in fuel cells, advanced gas turbines, microturbine generators, fuel cells - microturbine hybrids, and advanced engines (internal combustion and Stirling). The advanced gas turbine (AGT) and internal combustion engine technologies internal combustion will be used for the more near-term new generation and replacement of retired old steam plants. The other EPAG technologies are viewed as needing more time to become commercially available. Many EPAG technologies have bulk, intermediate and distributed generation potential.

Development over the last decade has resulted in relatively high efficiency gas turbine electric power plants, while fuel cells have only entered limited or niche markets. Commercially available gas turbines achieve efficiencies from 35 to 42 percent in simple cycle operation, depending on the scale and type of machine. In large combined cycle (300-400MW) operation, net efficiency approaching 60 percent is common. This compares favorably against existing gas-fired steam plants with best efficiency of approximately 35 percent in base-load operation of the most modern units; fleet efficiency for gas-fired steam units is much lower, probably in the mid-20 percent range, depending on operating conditions.

Fuel cells and high-performance turbine-based cycles may reach electrical generation efficiencies of about 60 percent. Researchers believe that combining a fuel cell operation with a gas turbine can result in over 70 percent efficiency in "hybrid" power plants by the year 2010.

In ER 96, the aging existing steam units are forecasted to generate 140,000 GWh in 2010. Installing EPAG technologies could yield economic and environmental benefits. Reducing the average cost of this generation by 0.1-0.2 cents per kWh will amount to savings in the range of $140-280 million per year. In addition, the achievement of an average 50 percent efficiency level would reduce CO_2 emissions by over 50 percent (16 million tons per year) and NOx emissions from 100,000 tons per year to only a fraction of this amount. In the longer term, a 70 percent efficient natural gas-fueled power plant of the future would pollute even less.

II. MAJOR ISSUES AND TECHNICAL GOALS: Because the relatively high cost of electricity, the Energy Commission staff held approximately 40 focus group meetings and received stakeholder input on how the PIER Program could help reduce this cost. Based on stakeholder input during some of these meetings, it became clear that research

on new EPAG technologies and strategies is needed to produce and deliver electricity at lower cost and with decreased environmental impacts. Based on stakeholder input and comments from the PIER Policy Advisory Council and Commissioners, staff developed the four major issues listed below.

The process of identifying technical goals began with a review of the results of focus group meetings in the subject areas of advanced gas turbines, fuel cells and a generic meeting on EPAG technologies. These market and technical goals were consolidated and refined, and other goals were added by staff in context of the four major issues.

The next step was to prioritize the technical goals. Staff used an approach based on the "energy future scenarios" developed by Lawrence Livermore National Laboratory. Staff's objective was to select goals for R&D funding that are relevant regardless of the scenario. Each of the technical goals as examined against a baseline scenario for expected benefits under the scenarios of high economic growth, environmental preference, and high energy prices. The selected prioritized technical goals will produce benefits across multiple scenarios and will become the basis for the EPAG program.

Issue A. Reducing the cost of electricity through significant advances in generation efficiency are limited by the technologies currently used in commercially available generation systems.

Most present development efforts result in only small improvements in generation efficiency. Innovative approaches to RD&D in science, technologies, and systems are needed to achieve improvements in efficiency which are not adequately funded by the commercial sector because of the high risk. Funding is needed to encourage manufacturers to participate in the development of environmentally-preferred advanced cycles, new technologies, and synergistic hybrid systems and applications.

Technical Goals:

1. Existing higher efficiency EPAG technologies need to improve reliability through the use of better materials and reduced operation and maintenance requirements.
2. Innovative hybrid combinations of cycles or applications need to be developed and demonstrated which will improve overall efficiency while meeting the thermal and/or electrical needs of end users.
3. EPAG technologies need to reduce the cost of generating electricity through improved operating efficiencies and reduced capital costs.
4. Novel EPAG cycles that have the ability to become commercially viable need to be developed and demonstrated.

Issue B. System reliability and the cost of electricity are adversely affected by California's large inventory of outdated steam power plants.

Aging central station power plants with existing infrastructure cannot operate economically in a deregulated electricity market. In addition to raising the cost of electricity, the operating limitations of these plants may also contribute to decreased system reliability and overall higher emissions. Must-run generation status in transmission constrained areas of the State (and elsewhere) results in very poor thermal efficiency and high risk of system failure should one or more plants fail unexpectedly. Research is needed to develop and demonstrate environmentally preferred technologies capable of superior performance, thus allowing the older plants to be retrofitted, replaced or retired.

Technical Goals:

1. EPAG technologies need to develop and demonstrate instrumentation, control systems, protocols and software tools that will minimize operator interface requirements.
2. EPAG technologies need to demonstrate favorable cost, efficiency, reliability and other performance characteristics so they can compete in a utility system environment that includes natural gas fired merchant power plants.
3. EPAG technologies need to demonstrate that they can cycle and load follow while maintaining high reliability, high fuel-to-electricity efficiency, high equipment durability and low emissions.
4. The advancement of distributed power generation technologies and their potential effects on the power generation system needs to be addressed.

Issue C. New cost-effective pollution control technologies are needed to reduce the health and environmental impacts from power plant emissions.

As environmental and health concerns grow, current emission controls for generation technologies are not likely to satisfy anticipated Federal, State, and local air pollution limits in the future. In addition to needing improved mitigation without the use of hazardous materials, reduced capital and operating costs are needed to assure market acceptance. RD&D is needed to find cost-effective and benign means of emissions control for all generation combustion systems.

Technical Goals:

1. A better understanding of combustion processes is required to reduce the need for post-combustion or add-on emission controls.
2. There is a need to develop EPAG technologies and demonstrate that they can significantly reduce environmental impacts (e.g. technologies that emit significantly less pollution than state-of-the-art combustion).
3. The potential for using mixed fuels or co-firing should be investigated as a means of reducing emissions or disposing of toxic materials.

4. EPAG technologies need to reduce the cost of complying with future air quality requirements without adversely affecting cost or energy conversion efficiency.

Issue D. Small and intermediate scale environmentally-preferred power generation technologies and systems are needed that can be efficiently and cost-effectively used as distributed generation resources.

In a restructured market, distributed generation has the potential to reduce the cost of electricity, improve local power quality, increase system reliability, postpone or eliminate the need for new or expanded transmission and distribution facilities, and improve the environment. Environmentally-preferred advanced generation technologies needed to facilitate distributed generation are not ready for the marketplace. RD&D is needed to encourage and accelerate development and application of these technologies.

Technical Goals:

1. Automated instrumentation and controls systems need to be developed and demonstrated which allow for remote operation of EPAG technologies in distributed generation applications.
2. EPAG technologies need to be packaged into standardized units in order to reduce siting time and permitting costs for distributed generation applications. These packaged units need to be sized (both physical and capacity) to meet end users' requirements.
3. EPAG technologies need to demonstrate and quantify value-added benefits (e.g. improve power quality and reliability) to the end user.
4. Less expensive EPAG technologies, suitable for distributed generation applications, need to be developed and demonstrated.

Summary of Technical Goals:

Since there is considerable overlap in the technical goals and in order to make the identification of funding objectives more concise, the prioritized technical goals were consolidated into the following four EPAG program sub-categories (note, numbers and letters in parentheses refers to the major issues and technical goals discussed above):

1. Demonstrate improved EPAG technology operating performance by improving reliability, reducing cost, improving efficiency and durability, and demonstrating benefits (issues A.1, A.3, B.2, B.3,B.4, D.3 and D.4).

2. Develop and demonstrate innovative EPAG cycles by testing hybrid combinations of cycles or applications, developing novel cycles, and evaluating the potential for using mixed fuels or co-firing (issues A.2, A.4, and C.3).
3. Develop packaged standardized EPAG units by making the system less dependent on operator interface, developing automated instrumentation and controls for remote operation, and standardizing units in sizes to meet end users' needs (issues B.1, D.1 and D.2).
4. Provide Environmental benefits improvement by better understanding the combustion process, quantifying the environmental benefits and complying with future environmental constraints without compromising efficiency (issues C.1, C.2 and C.4).

III. OBJECTIVES:

Long-Term Vision:

As we enter the next century, the demand for new and replacement generation that will meet or exceed increasingly more stringent environmental requirements will grow. Therefore, the vision of this program is to 1) support development of new EPAG technologies and 2) significantly increase the performance and cost effectiveness of existing EPAG technologies and applications which will result in their widespread use in California. This increased use of EPAG technologies will also reduce California's overall environmental impact caused by the generation of electricity.

The R&D effort and resources needed to move EPAG technologies into the market exceeds funding available from the Energy Commission. Additionally, PIER EPAG funding is small relative to EPAG R&D sponsored by other R&D institutions. Thus, close coordination with these institutions is critical to minimize duplication of effort, leverage other funding and ensure these institutions consider the issues of greatest importance to California.

Specific Objectives: The initial EPAG program objective is to increase energy efficiency and economic effectiveness of power generation through the development and commercialization of environmentally benign power generation systems operating in multiple end use sectors.

More specifically, the program objectives are to develop and demonstrate cost effective advanced gas turbine systems with 60 percent efficiency without a steam-bottoming cycle and fuel cell systems and other advanced power generation systems which can be successfully commercialized in niche markets over the next 2-10 year period. The program objectives also are to continue supporting other research and development

activities on fuel cells and microturbine generator technologies that can mature and become available for commercialization beyond the next 10 years period.

Additional specific objectives, that will set the stage for future program directions for each technical sub-category, need to be developed that are consistent with the R&D plans of other institutions and developed with active input from EPAG stakeholders.

Near-term objectives for fuel cells. Near term objectives are 1). To characterize fuel cell markets needs, 2) to obtain a better understanding of fuel cell and fuel cell hybrid design and operational issues by means of computer modeling and computer simulations, 3) to identify steps toward power conditioner unit cost reduction and reliability improvement, issues that affect microturbines, photovoltaic systems, and wind electricity generators also, and 4) to continue the early development of a new class of solid oxide fuel cells.

Near-term objectives for advanced gas turbines and other EPAG technologies. Near term objectives for advanced gas turbine technologies will depend on the combined and collaborative efforts of multiple parties involved in supporting and performing the work.

Overall objectives are to improve fuel-to-electricity efficiency by 10 percent, to achieve minimal environmental impact, and to reduce the cost of electricity for all technologies in all applications.

IV. CURRENT FUNDING

Commission EPAG Projects - Currently there are 14 PIER EPAG projects totaling $11.1 million that have been approved by the Energy Commission as part of the Transition and the First and Second PIER General Solicitations. In addition, two other EPAG project for $516k are pending Commission approval. Of these projects, six address the first EPAG sub-category, three address the second, three address the third, three address the fourth and two-address technology transfer which cuts across all four sub-categories. These projects are listed in Table 1 and discussed in more detail in Attachment 1.

TABLE 1

PIER ENVIRONMENTALLY PREFERRED ADVANCED GENERATION PROJECTS

Contract #	EPAG Transition Solicitation Contracts	Contract Amount
500-97-012	Solid-Oxide Fuel Cell/Micro Turbine Generation Hybrid	$2,000,000
500-97-011	Distributed Resources Demonstration	$450,000
500-97-013	Formation of NOx in Industrial Gas Burners	$335,000
500-97-011	Fuel Cell Development and Demonstration	$300,000
500-97-012	Micro Turbine Generator (Distributed Generation)	$500,000
	Subtotal – Transition Contracts	$3,585,000
	EPAG First General Solicitation Contracts	
500-97-039	75-kW Molten-Carbonate Fuel Cell Stack Verification Test	$1,000,000
500-97-031	Low NOx Gas Turbine Combustors for Distributed Power Generation	$878,788
500-97-042	Ultra High-Efficiency Packaged Microcogeneration System	$1,035,420
500-97-038	A Novel Steam Reforming Reactor for Fuel Cell Distributed Power Generation	$349,852
500-97-045	Megawatt-Class Pressurized Solid Oxide Fuel Cell/Gas Turbine Power System Demonstration Project	$550,000
500-97-033	Durability of Catalytic Combustion Systems	$1,316,303
500-97-041	Energy Efficient, Low Emission, Cost Effective MicroPilot Ignited Natural Gas Engine Driven Genset for Deregulated, Distributed Power Generation Markets	$$982,528
	Subtotal First General Solicitation Contracts	$6,112,891
	EPAG Second General Solicitation Contract	
500-98-040	Intelligent Software Agents for Control & Scheduling of Distributed Generation	$554,010
500-98-041	Catalytic Combustor – Fired Industrial Gas Turbine for Distributed Power & Cogeneration Application	$814,543
	Subtotal – Second General Solicitation Contracts	$1,368,553
	Other EPAG Contracts (Pending)	
500-98-51	Analyses and Technology Transfer for Fuel Cell Systems	$305,733
MEM-97K-031	To Expand and Utilize the Capacity of the National Fuel Cell Research Center Program (Technology Transfer for Fuel Cell Systems)	$210,000
	Subtotal other EPAG Contracts	$515,733
	Total EPAG Contracts	**$11,528,177**

EPAG R&D being conducted by others - At this time, US DOE is the major source of funds (over $150 million since 1992) for R&D on fuel cells, microturbine generators, and advanced energy storage systems. Additionally, DOE has committed $700 million since 1994 to the Advanced Turbine System Program, currently under way and planned to have new engines in the field by 2002. Other federal agencies, such as Department of Commerce through its National Institute of Science & Technology (NITS), Department of Defense through its Advanced Research Projects Agency (ARPA/DARPA), and Environmental Protection Agency (EPA) have also funded some R&D projects for fuel cells and advanced energy storage systems.

Several national laboratories, such as Lawrence Livermore Lab, Argonne National Lab, National Renewable Energy Lab, Los Alamos National Lab, and Sandia National Lab also have R&D programs for advanced power generation technologies.
The Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI) are coordinating RD&D activities of national electric and gas utilities and some international utilities for advanced power generation technologies and systems.

Among the state energy organizations, California Energy Commission (CEC) and New York State Energy Research and Development Authority (NYSERDA) are the major advanced power generation R&D funding organizations. National Fuel Cell Research Center - University of California Irvine, University of Utah, University of Florida, University of Missouri, University of Pennsylvania, University of Texas, and Desert Research Institute - University of Nevada are some of the universities having fuel cell R&D programs.

Several private companies actively involved in fuel cell R&D with funding primarily from federal agencies are: Energy Research Corporation and MC -Power (Molten Carbonate), Allied Signal (Solid Oxide and Proton Exchange Membrane Fuel Cells and Microturbine Generators), Seimens, Westinghouse Electric Corporation and Ztek Corporation (Solid Oxide fuel cells and Microturbine Generators and hybrid systems), Seimens Westinghouse Electric Corporation / Ballard Generation Systems / H-Power / Energy Partners,Avista Corporation and Plug-Power (Proton Exchange Membrane Fuel Cells), International Fuel Cells Corporation and ONSI (Phosphoric Acid). Several of these private companies are hopeful of introducing commercially available advanced power generation products for a variety of distributed power generation niche markets, including residential and commercial applications, over the next 2-10 years period. In addition, several companies have been awarded contracts for advanced fuel cell - microturbine generator hybrids.

V. PROPOSED FUNDING FOR FY 1998/99 and FY 1999/00 -

The proposed funding (to be encumbered) for the EPAG program during FY 1998/99 is $4 million. As

discussed below, this funding is in four general areas: programmatic, fuel cells, advanced gas turbines and other technologies, and innovative projects.

In addition, once the EPAG program has conducted the market analysis and prepared the technology roadmaps discussed below, approximately $17 million additional funding will be needed in FY 1999/00 for several new projects and continuation of some existing projects.

Programmatic Funding– Since the EPAG program has limited funding, effective coordination is a key element for overall program success. An important and necessary preliminary activity, therefore, is assembling a team for technical and administrative support. The team would be led by staff and would:

- Identify and characterize California markets for EPAG technologies and their applications. This market analysis will be used to develop technology "roadmaps" that define the technical issues that must be resolved to successfully compete in those markets; thus ensuring a "market pull" focus for R&D funding in the program. To facilitate this "market pull" strategy, the EPAG team will endeavor to initiate and cultivate synergistic relations with collaborative partners having similar RD&D interests and to assure representation of the California perspective. These parties will include, but not be limited to, the United States Department of Energy (DOE), equipment manufacturers, universities, private research institutions, national laboratories and industry- related special interest group.
- Provide assistance in evaluating and possibly managing collaborative efforts that bring industry stakeholders into the planning and decision-making process.
- Identify EPAG benefits, targets, goals and funding opportunities for the program. This should include an analysis of the likely EPAG technologies' distributed generation benefits to the end user and the electricity system.
- Leverage DOE and other national R&D programs and encourage emphasis on California's EPAG issues.

This team would augment staff resources and help ensure our California focus is complementary to other R&D initiatives in the United States. Ideally the team would be drawn from the EPAG R&D infrastructure to take advantage of this existing knowledge base. By drawing upon this infrastructure, project-funding decisions are more likely to fulfill the objectives of improving operating performance, developing innovative cycles and hybrid systems, standardizing package systems, and reducing adverse impacts to the environment.

In particular, the team would assist staff in an analysis of the major needs of industry decision-makers in these markets. Although the projects funded will likely be technology or application specific, the analysis of market needs will help to ensure that

the R&D is relevant because funding decisions will be based on the needs of the major California EPAG markets.

The team will also assist staff in evaluating the interest of stakeholders in possibly forming one or more collaborative to address R&D needs of selected EPAG technologies. These collaboratives will include those entities most likely to transfer successful R&D into the marketplace and is a critical element because it assures "real time" and ongoing feedback on the changing needs of the restructured market.

Finally, since staff is interested in minimizing the administrative burden of managing contracts selected under the EPAG program, the team may identify outside organizations that have the expertise and resources available to better manage projects. Thus, as projects are selected for funding, a decision will be made on whether staff or an outside organization is better suited to manage the projects.

The major steps for implementing this programmatic approach are:

1. Identify needed technical and administrative resources and create a team through either the existing technical support contract, an alternate sole-source contract or programmatic solicitation.

2. Build on existing work by conducting an extensive review of numerous "roadmaps", "strategic plans", and "visions created by national research institutions.

3. Refine earlier EPAG market decision-maker analyses using a combination of economic modeling and focus group meetings. The goal of this effort is to define the characteristics (capacity, emissions, cost, footprint, etc.) of EPAG machines that will successfully compete in selected market(s).

4. Assess stakeholder interest in participating in EPAG collaboratives for major technology areas including gas turbines, fuel cells, hybrid systems, and advanced engines. These collaborative would be led by staff, include stakeholder representatives, and use a "consensus" approach to identify markets, machine characteristics, technical issues and resolution strategies. The collaborative is also a forum for identifying possible funding partners for R&D projects

5. Use collaborative recommendations to help define technology "roadmaps" specific to California.

The products of this effort will be technology "roadmaps". These "roadmaps" define the current status of the technology, the characteristics of a competitive technology and the major technical goals that need to be addressed to achieve this competitive technology.

This work should be initiated through an interagency agreement.

This activity relates to all four major issues by facilitating better decision making because it draws upon the collective wisdom of the EPAG research community therefore selected research will be connected to the needs of the market

Fuel Cells:

(Note, that numbers and letters in parenthesis refer to the major issues and technical goals discussed in section II)

1. Dynamic Models for Fuel Cell Components, Fuel Cell Systems, and Hybrid Systems.

There are four major fuel cell types under development for terrestrial use (and a fifth type in the study stage) with different operational characteristics, different subsystems or components, different technical issues, and with different potentials to be integrated with other generating sources to achieve higher efficiency. Understanding fuel cell systems and issues will be facilitated by modeling fuel cell systems and simulating their operation

Dynamic computer models can and should be used to guide fuel cell power plant design, to identify potential problems on paper before they are embedded in hardware, and to influence Energy Commission decisions on funding future proposals. Dynamic modeling of fuel cell and of fuel cell hybrids has been started at the U.S. Department of Energy (DOE) Federal Energy Technology Center (FETC) and at the University of California, Irvine, National Fuel Cell Research Center (NFCRC) under a Cooperative Research and Development Agreement (CRADA).

This CRADA should be funded in FY 1998/1999 and FY1999/2000 under an inter-agency agreement. (Issues A.1, A.2, A.4, B.2, C.3).

2. Fuel Cells Market Assessment.

A fuel cell market assessment will be performed as part of the collaborative EPAG planning process. More definitive market assessments are required to fully define fuel cell market opportunities and to identify physical and institutional infrastructure needs.

This should be funded by a competitive solicitation in FY 1999/2000. (Issues A.4, B.2, D.2, D.3, D.4).

3. Power Conditioner Unit (PCU) Research, Development and Demonstration Needs Definition.

Fuel cells produce direct current (DC) electricity which must be converted to alternating current (AC) for use. An "inverter" does this conversion. The inverter when packaged with control systems, meters and other electronics is called a power conditioning unit (PCU). The terms "inverter" and "PCU" are often used interchangeably to indicate the whole packaged system. Microturbines, photovoltaic (PV) systems and wind turbines also need PCUs.

PCUs have two problems. First, they have high capital cost, on the order of 50 cents to $1 per watt or $500 to $1000/kW in sizes below 100 kW. This is on the order of the capital cost of an entire combined cycle power plant. If fuel cells, microturbines, and PV systems are to be cost competitive, PCU capital cost must come down. Second, PCUs historically have been unreliable in certain fuel cell and other applications.

There is a need to define the nature of the PCU problem with respect to capital cost as a function of size, cost reduction potential resulting from circuitry improvement, potential to incorporate US DOE/U.S. Department of Defense (DOD) Power Electronic Building Block (PEBB) circuitry into PCUs, cost reduction potential resulting from volume production, manufacturing and marketing issues, and control circuitry required for different DC sources. The study should be done in collaboration with industry and the DOE and DOD to assure that the findings are transferred to PCU manufacturers and EPAG system suppliers.

This work should be coordinated with the PIER Renewables Team and should be initiated through an open competitive solicitation in FY 1998/1999. (Issues A.1, A.3, B.1, B.2, B.3, C.2, D.1, D.2)

4. Fuel Cell Performance Analysis Tools

Until recently the only fuel cell offered for commercial sale was the ONSI 200 kW phosphoric acid fuel cell. Proton Exchange Membrane Fuel Cell (PEMFC) and Solid Oxide Fuel Cell (SOFC) systems are being installed as demonstrations, and they may be offered for commercial scale within the next few years.

Continuation of the Fuel Cell Analysis Tools development as initiated under Energy Commission funding at the National Fuel Cells Research Center is needed for two reasons. First, fuel cell systems need to be optimized to each application for their full efficiency benefits to be realized. Second, fuel cells qualify for the Emerging Renewable Resources Buydown Program if fueled by sewer gas, landfill gas, or other hydrogen-rich gases. Standard methods for testing fuel cells and analyzing their performance are needed to protect the public interest. The development of the analysis tools should be supplemented by field monitoring of a select number of fuel cells installed under the Buydown Program. The field test data would serve to validate the Analysis Tools.

This work should be continued in FY 1999/2000 through an inter-agency agreement. (Issues A.1, A.2, A.4, B.2, C.3).

5. Planar Solid Oxide Fuel Cell Development for Operation at 650°C.
Planar solid oxide fuel cells (SOFC) have many practical advantages over other fuel cell types, including the ability to do away with a fuel-to-hydrogen reformer. However, currently available ceramic materials require high temperature (850°C-1,000°C) operation. This high temperature of operation puts severe limitations on the choice of other fuel cell components. A lower temperature of operation would allow conventional metals to be used for some of the fuel cell components and would also yield higher fuel-to-electricity efficiencies. Research to develop this lower temperature SOFC should be funded.

This work should be initiated in FY 1998/1999 through a competitive negotiation or an Open Competitive Solicitation. (Issues A.1, A.3, B.2, C.3, C.4, D.4).

Advanced Gas Turbines And Other Technologies:
(Note, that numbers and letters in parenthesis refer to the major issues and technical goals discussed in Section II)

Microturbine Generators.
Microturbine Generators (MTGs) are commercially available or nearly available from several manufacturers. Their use to date has been primarily in niche markets where premium power was unavailable from other sources. As a result, historically, the capital cost has been high and the fuel efficiency and reliability, availability, maintainability, and durability (RAMD) have been low. One manufacturer has made a significant market entry with commitments to deliver nearly 3000 units in 1999and 10,000 units in 2000. Orders have been received from well-known national chains in the food service and retail sectors. These early units will be installed in simple cycle duty (power only with no exhaust heat recovery). Brochure information on these 75kw units claims fuel to electric efficiency at nearly 30% on natural gas, (less fuel compressor, if needed), 95% availability, and design life of 40,000 hours (expressed as nominally 10 years, indicating the expectation of cycling operation).

In view of the commercial availability of at least one system with performance specifications acceptable to some corporate buyers, the participation of PIER in co-funding RD&D becomes less urgent, but none the less appropriate. Research efforts should be directed toward enhancing product performance, hence enlarging the body of potential applications and increasing the public benefit attendant to implementation of MTGs in both distributed and dispersed service. Therefore, EPAG funding for FY 1998/99 and FY 1999/00 should include:

1) Users face the cost of grid interconnection if they intend to generate in parallel with utility power or shed excess capacity to the grid. Rules and equipment requirements vary widely between service territories, resulting in higher costs and associated uncertainties. This represents a major barrier to cost-effectiveness and buyer confidence, thus preventing wide spread technology adoption. PIER supported studies and research directed toward unifying and standardizing interconnection requirements that would provide significant benefit to the rate-payer considering the purchase of an MTG. PIER co-funding should support studies already under way by Institute of Electrical and Electronic Engineers (IEEE) and other industry groups. Most of these are proceeding on an ad hoc basis with most, if not all, participants volunteering their time and effort. PIER funding, in cooperation with match funding from engine manufacturers, interconnection equipment manufacturers, utilities, and industry groups, would accelerate the development and adoption of cost-effective and uniform interconnection standards.

This effort should be coordinated with the PIER Renewables Program since many of those technologies face the same interconnection issues. This effort should be initiated through an open solicitation in FY 1998/99. (Issues A.1-4, B.1-2, D.1-4)

2) Power conditioning for non-synchronous generators and alternators imposes another system element and package cost on the MTGS. For units that must convert power output to 50/60 hertz, the inverter package can account for up to 50% of the package cost. The goal of this research would be to improve the performance and reduce the cost of power conditioning equipment. This RD&D effort should be closely allied with similar efforts in fuel cell power conditioning development.

This work should be coordinated with the Renewables PIER Team and should be initiated through an open competitive solicitation in FY 1998/99. (Issues A.1-4)

3) In order to support and gain market acceptance of MTGs, validation of this technology should be provided by a neutral third party institution. This researcher would conduct RAMD studies with independent testing contractors to determine unit performance and variable O&M requirements. In concert with manufacturers, this testing would provide a higher level of consumer confidence and enable better-informed buying and selection decisions. This work should be initiated in FY 1998/99. (Issues A.1-4, B.1, B.4)

Industrial and Larger Scale Gas Turbine Combustion.

Industrial and larger scale gas turbines have received significant RD&D attention since 1994 through the DOE Advanced Turbine Systems (ATS) Program. This $700 million Federal program had as its goal the accelerated improvement in performance of industrial and bulk

power gas turbines. Work toward efficiency gains of 10+% and NOx emissions reductions to 10 ppm without Selective Catalytic Reduction (SCR) over previous commercial products has almost been completed by four major engine manufacturers.

In the process of the ATS Program there have emerged several research opportunities not originally envisioned in the ATS Program itself. Many of these are relatively low cost activities and should be pursued by the EPAG program utilizing many of the researchers and institutional infrastructure already in place. The most important of these activities are:

1) Study lean premix combustion issues, including stability, premixing, and preheating. The Federal Energy Technology Center (FETC), engine manufacturers, several universities, several national laboratories and several combustor manufacturers are capable of doing this work. FETC has proposed a specific two-year effort in cooperation with Solar Turbines to study combustor acoustic signatures as a means of measuring flame stability.

   Premix combustion research should be funded by a competitive solicitation in FY 1998/99.(Issues A.3, B.2, C.1-4)

2) Alzeta Corporation, a California manufacturer, has developed a novel combustion technology and is successfully developing it toward gas turbine applications. Alzeta Corporation has brought ultra low NOx combustor products to market and has been working cooperatively with several gas turbine manufacturers under the PIER and other Commission programs. The ultra low (less than 3 ppm) gas turbine combustor effort currently funded by PIER is almost to the point of prototype combustor testing in a single combustor engine or single combustor test rig. Completion of this work is expected by the end of calendar year 1999.

   Funding through sole source should be in early FY 1999/00. (Issues A.3, B.2, C.1-4)

3) Catalytic combustion has begun to emerge as a viable alternative to costly exhaust clean up schemes for reduction of NOx emissions. Additional on-going support is needed to refine and extend the capabilities of the technology. The PIER program should continue existing support of the RD&D work under way in this area by Catalytica Combustion Systems and Solar Turbines, both California companies.

   A study in RAMD, sensitivity to fuel composition variability, operation on liquid fuels, and sensitivity to fuel and air contaminants should be funded by competitive negotiation in FY 1999/00. (Issues A.3, B.2, C.1-4)

4) In order to follow the demand of the electricity system, some generators will be constantly varying their output and some will cycle their units on and off. This is generally considered to be intermediate load and because of its size of dynamic nature it can create havoc with the grid if it is not properly managed. A study on how to most efficiently and reliably supply power for the intermediate load should be closely coordinated with the PIER Strategic program since reliability is a major strategic issue.

This study should concentrate on identifying the most capable means of generating efficient, reliable intermediate load power, including, but not limited to the development of a new class of gas turbine designed specifically for cycling duty.

This effort should be initiated in FY 1998/99 and may be incorporated into the EPAG Programmatic Funding. (Issues A.3, B.2, C.1-4)

5) Significant advances remain to be made in the theoretical understanding of fuel lean combustion. While many of the issues are product specific and should be pursued by engine manufacturers, there are some issues of generic concern that should be investigated on a cooperative basis. These studies should include further development of analytical and modeling tools for three-dimensional computational fluid dynamics, combustion chemical kinetic mechanisms, and other phenomenological studies proposed by industry.

A theoretical understanding of fuel lean combustion should be funded by as competitive solicitation in FY 1998/99. (Issues A.3, B.1, C.1-4)

Innovative Projects for FY 1998/99 and FY 1999/00

This activity would expand the existing PIER Energy Innovation Small Grants Program by providing additional funds and by possibly increasing the current maximum funds available for single EPAG innovative projects. This will allow for funding EPAG projects during FY 1998/99 and FY 1999/00 that are not included in the funding areas listed above and that address one or more of the Four EPAG major issues and their respective technical goals.

This work should be initiated in FY 1998/99 via a modification to our existing inter-agency agreement with the California State University Institute.

ATTACHMENT 1
EXISTING ENVIRONMENTALLY PREFERRED ADVANCED GENERATION PROJECTS

PIER Transition Projects[T]

First PIER Solicitation[1]

Second PIER Solicitation[2]

Others[3]

- [T] *Project Title:* ***Solid-Oxide Fuel Cell/Micro Turbine Generation Hybrid***

  The purpose of this $2,000,000 contract with Edison Technology Solutions is to demonstrate the proof-of-concept testing of the integration of a solid-oxide fuel cell and a micro turbine into a hybrid generation system that could offer significant efficiency and environmental advantages.

  Contractor Project Manager: Stephanie Hamilton (626) 815-0514

  CEC Project Manager: Avtar Bining (916) 657-2002

- [T] *Project Title:* ***Distributed Resources Demonstration***

  The purpose of this $450,000 contract with SDG&E is to demonstrate how fossil fuel based distributed generation systems can be seamlessly integrated into an existing electric distribution system.

  Contract project Manager: Al Figueroa (619) 654-8614

  CEC Contract Manager: Jamie Patterson (916) 657-4819

- [T] *Project Title:* ***Formation of NOx in Industrial Gas Burners***

  The purpose of this $335,000 contract with the University of California-California Institute for Energy Efficiency is to develop technologies to attain and maintain energy-efficient operation of natural gas industrial burners and stationary gas turbines with ultra-low emissions of nitrogen oxides.

  Contractor Project Manager: Jim Cole (510) 486-4123

  CEC Project Manager: Matt Layton (916) 654-3868

- [T] *Project Title:* ***Fuel Cell Development and Demonstration***

  The purpose of this $300,000 contract with SDG&E is to assist in the advancement of molten-carbonate fuel cell technology by testing a 75 kW fuel cell stack.

Contract Project Manager: Al Figueroa (619) 654-8614

CEC Contract Manager: Avtar Bining (916) 657-2002

- [T] *Project Title:* ***Micro Turbine Generator (Distributed Generation)***

  The purpose of this $500,000 Contract with Edison Technology solutions is to develop and test small gas turbine (30-60 kW) generation technology based on extrapolating an automotive design into a land-based generation unit.

  Contractor Project Manager: Stephanie Hamilton (626) 815-0514

  CEC Project Manager: Avtar Bining (916) 657-2002

- [1] *Project Title:* ***75-kW Molten-Carbonate Fuel Cell Stack Verification Test***

  The purpose of this $1,000,000 contract with M-C Power Corporation is to design and test a 75 kilowatt molten-carbonate fuel cell power generating system.

  Contract Project Manager: Thomas Benjamin (630) 986-8040, Ext. 159

  CEC Contract Manager: Avtar Bining (916) 657-2002

- [1] *Project Title:* ***Low NOx Gas Turbine Combustors for Distributed Power Generation***

  The purpose of this $878,788 contract with Alzeta Corporation is to test a low NO_x combustor in gas turbines and turbine test cells.

  Contract Project Manager: Dr. Scott Smith (408) 727-8282

  CEC Contract Manager: Dave Hatfield, P.E. (916) 654-7119

- [1] *Project Title:* ***Ultra-High-Efficiency Packaged Microcogeneration System***

  The purpose of this $1,035,420 contract with Aero Vironment, Inc. is to develop and demonstrate an ultra-high-efficiency packaged micro-cogeneration system.

  Contract Project Manager: Alec Brooks (626) 357-9983

  CEC Contract Manager: Shahid Chaudhry (916) 654-4858

- [1] *Project Title:* ***A Novel Steam Reforming Reactor for Fuel Cell Distributed Power Generation***

  The purpose of this $349,852 contract with Energy and Environmental Research Corporation is to develop and evaluate catalysts and sorbents for a steam reforming process within fuel cell systems.

  Contract Project Manager: Jerald Cole (949) 859-8851

  CEC Contract Manager: Avtar Bining (916) 657-2002

- [1]*Project Title:* ***Megawatt-Class Pressurized Solid Oxide Fuel Cell/Gas Turbine Power System Demonstration Project***

  The purpose of this $550,000 contract with Westinghouse Electric Company is to design a mega-watt class pressurized solid oxide fuel cell/gas turbine power system.

  Contract Project Manager: Dr. Stephen E. Veyo (412) 256-1901

  CEC Contract Manager: Prab Sethi, P.E. (916) 654-4509

- [1] *Project Title:* ***Durability of Catalytic Combustion Systems***

  The purpose of this $1,316,303 contract with Catalytica Combustion Systems, Inc. is to develop and demonstrate a catalytic combustion system.

  Contract Project Manager: Tom Morjig (650) 940-6371

  CEC Contract Manager: Dave Hatfield, P.E. (916) 654-7119

- [1] *Project Title:* ***Energy Efficient, Low Emission, Cost Effective MicroPilot Ignited Natural Gas Engine Driven Genset for Deregulated, Distributed Power Generation Markets***

  The purpose of this $982,528 contract with the Gas Research Institute (GRI) is to develop and demonstrate a micropilot-ignited natural gas engine.

  Contract Project Manager: Lou A. Lautman (773) 399-5461

  CEC Contract Manager: Shahid Chaudhry (916) 654-4858

- [2] *Project Title:* ***Intelligent Software Agents for Control & Scheduling of Distributed Generation***

  The purpose of this $554,010 contract with Alternative Energy Systems Consulting, Inc. is to develop and demonstrate software for the scheduling and control of distributed energy resources in a competitive market.

  Contract Project Manager: Gerald L. Gibson (619) 560-7182

  CEC Contract Manager: Jamie Patterson (916) 654-4819

- [2] *Project Title:* ***Catalytic Combustor - Fired Industrial Gas Turbine for Distributed Power & Cogeneration Application***

  The purpose of this $814,543 contract with Solar Turbines, Inc. is to develop an ultra-low NO_x catalytic combustion system for industrial gas turbines in distributed power and cogeneration applications.

  Contract Project Manager: Dr. Ken Smith (619) 544-5539

  CEC Contract Manager: Dave Hatfield, P.E. (916) 654-7119

- [3]*Project Title:* **Analyses and Technology Transfer for Fuel Cell Systems**

  The purpose of this $305,733 PIER contract with the Regents of University of California (UC Irvine - National Fuel Cell Research Center) is to support the analyses and technology transfer for fuel cell systems at the NFCRC.

  Contract Project Manager: Dr. Scott Samuelsen (949) 824-5468

  CEC Contract Manager: Avtar Bining (916) 657-2002

- [3]*Project Title:* **To Expand and Utilize the Capacity of the National Fuel Cell Research Center Program (Technology Transfer for Fuel Cell Systems):** The purpose of this $210,000 Member Request Grant with the Regents of University of California (UC Irvine - National Fuel Cell Research Center) is to expand and utilize the capacity of the NFCRC programs including technology transfer for fuel cell systems.

  Contract Project Manager: Dr. Scott Samuelsen (949) 824-5468

  CEC Contract Manager: Avtar Bining (916) 657-2002

TOTAL FOR ENVIRONMENTALLY PREFERRED ADVANCED GENERATION PROJECTS: $11,582,177